MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

EME3046 - MECHANICS OF MATERIALS
(ME)

12 OCTOBER 2017
2.30 p.m.- 4.30 p.m.
(2 Hours, Open Book)

INSTRUCTION TO STUDENTS

1. This question paper consists of 7 pages with 5 Questions.

2. Questions 1 to 2 are **OPTIONAL**. Attempt only **ONE** out of the **TWO** questions.

3. Questions 3, 4 and 5 are **COMPULSORY**. You MUST attempt these questions.

4. All questions carry equal marks and the distribution of the marks for each question is given.

5. Please write all your answers in the Answer Booklet provided.

OPTIONAL

Question 1:

A strain rosette shown in **Figure Q1** was adhered to the top flat surface of a thin mechanical component for failure analysis. The strains recorded are as follows:

$$\varepsilon_1 = 500\mu \qquad \varepsilon_2 = -450\mu \qquad \varepsilon_3 = -75\mu$$

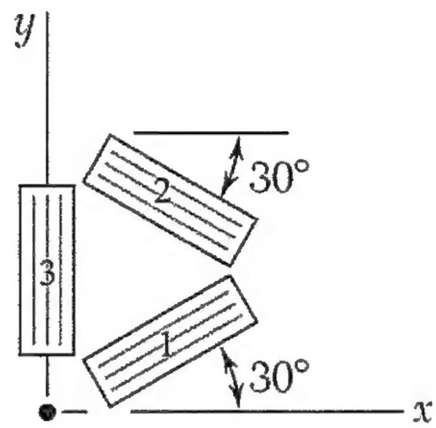

Figure Q1

Assume a state of plane stress. At the point of measurement,

a) determine:

i) the magnitude of the in-plane principal strains **[13 marks]**

ii) the in-plane maximum shear strain **[2 marks]**

iii) the true value of the maximum shear strain **[3 marks]**

b) using the Von Mises failure criterion, determine the factor of safety at the point, given the following material properties: Yield strength = 450 MPa, Young's Modulus = 200 GPa, and Poisson's ratio = 0.3. **[7 marks]**

[Hint]: You might find the following equation useful:

$$\varepsilon_i = \varepsilon_x \cos^2\theta_i + \varepsilon_y \sin^2\theta_i + \gamma_{xy} \sin\theta_i \cos\theta_i \qquad \text{(Eq. 1.1)}$$

Continued...

OPTIONAL

Question 2:

Given E = 70 GPa, G = 28 GPa, and x unknown, the following is the stress state at the critical point of a mechanical component:

$$\sigma = \begin{bmatrix} -225 & 150 & 0 \\ 150 & 125 & 0 \\ 0 & 0 & x \end{bmatrix} \text{MPa}$$

Assume a state of plane strain,

a) determine x. **[3 marks]**

b) determine the magnitude of the in-plane principal stresses. **[4 marks]**

c) draw a three-dimensional Mohr's Cirle to represent the stress state. Label the stress state, and the principal stresses clearly in your Mohr's Circle. **[5 marks]**

d) determine the direction of the in-plane principal stresses using the Mohr's Circle in **Question 2 part c)**. Express the principal directions using unit vectors. **[6 marks]**

e) determine the factor of safety of the critical point using the maximum shear stress criterion, and tensile yield strength of 300 MPa. State if the component is safe. **[7 marks]**

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COMPULSORY

Question 3:

An advertisement board above the street has a weight of 150 N. It hangs at the end of a 15-mm diameter bent steel rod as shown in **Figure Q3**.

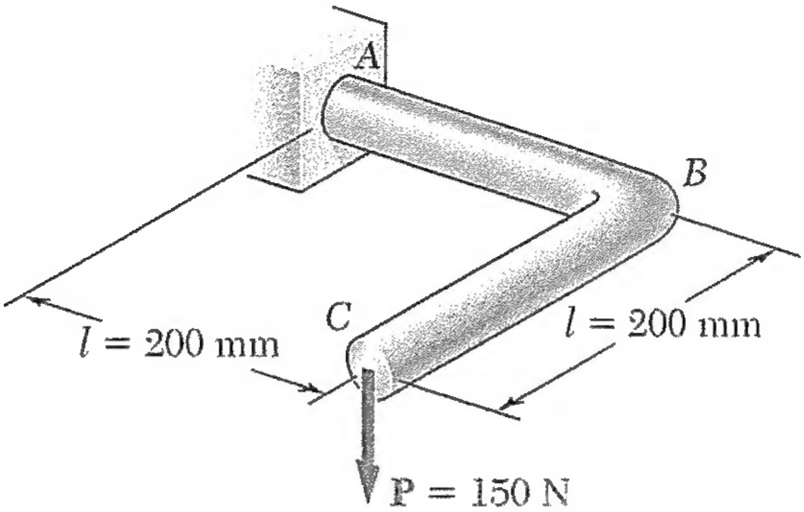

Figure Q3

Knowing that E = 200 GPa, G = 70 GPa, and considering only bending and torsional shear energy in the analysis:

a) determine the downward deflection at point C using the Castigliano's Theorem. **[21 marks]**

b) based on your analysis in **Question 3 part a)**, suggest four possible ways to reduce the deflection, given that the weight of the advertisement board is fixed. **[4 marks]**

Continued...

COMPULSORY

Question 4:

Figure Q4(a) shows a thin-wall tube with rectangular cross-section and constant thickness. Dimensions a and b are measured from the mid-thickness of the sides, and $b > a$. **Figure Q4(b)** shows a thin-wall tube with square cross-section, having the same thickness, t. Both cross-sections have the same area (i.e. same amount of material).

The rectangular tube was forged, while the square tube was made by folding sheet metal and welding at the slit as shown in Figure **Q4(b)**.

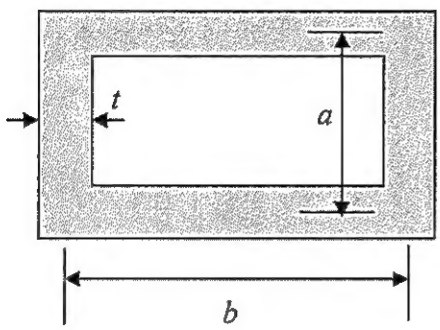

Figure Q4(a)

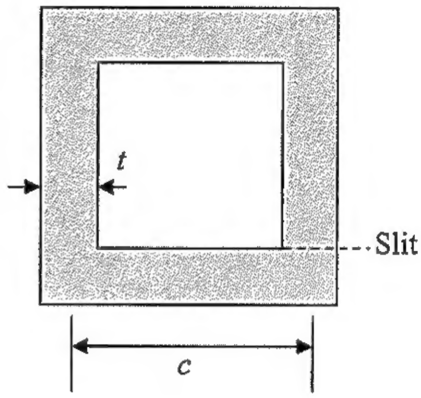

Figure Q4(b)

a) Compare the torsional stiffness, J, of both cross-sections, and identify the cross-section with the higher torsional stiffness. **[10 marks]**

b) Now, suppose the welded slit no longer holds. The section then becomes open. Estimate the change of torsional stiffness of the square tube, by giving the ratio of its torsional stiffness before and after the weld failure. **[5 marks]**

c) Determine the torsional stiffness of a round tube with the same area and same thickness in terms of t and c. **[7 marks]**

d) Give your conclusions of your analysis in part **a)**, **b)** and **c)** on the torsional resistance and the cost efficiency of the tubes. **[3 marks]**

Continued...

COMPULSORY

Question 5:

Figure Q5(a) shows a W200 × 22 structural steel ($E = 210$ GPa, $\sigma_Y = 360$ MPa) column that supports end moments of M = 8 kN-m about the *x-x* axis and unknown end axial forces of *P*. The column is fixed at both ends. The column section is shown in **Figure Q5(b)**.

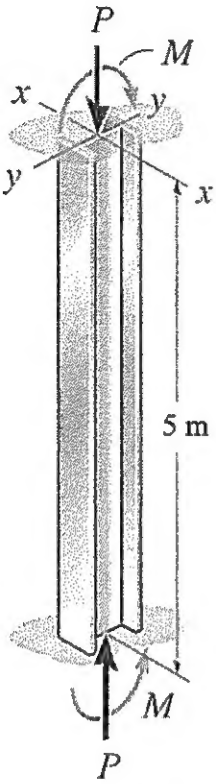

Figure Q5(a)

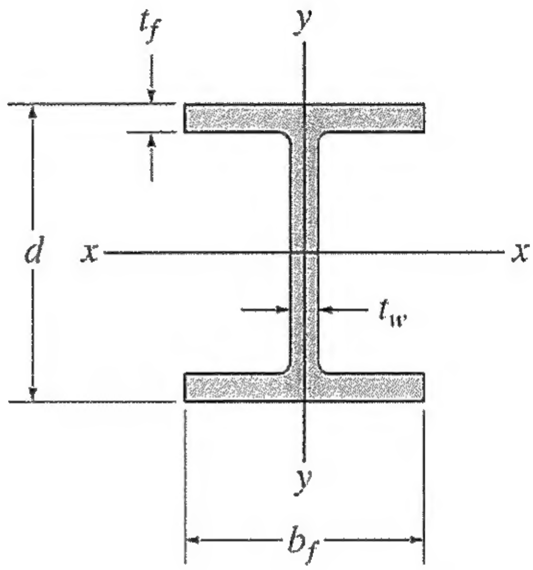

Figure Q5(b)

The properties of the column are given as follows:

Parameter	Quantity
Area (mm^2)	2860
Depth, d (mm)	152
Web thickness, t_w (mm)	5.84
Flange width, t_f (mm)	152.0
Flange thickness, b_f (mm)	6.6
Moment of inertia about x-x axis, I_{xx} (10^6 mm^4)	12.1
Radius of gyration about x-x axis, r_x (mm)	65.0
Moment of inertia about y-y axis, I_{yy} (10^6 mm^4)	3.87
Radius of gyration about y-y axis, r_y (mm)	36.8

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a) Using the AISC equations as follows:-

$$\sigma_{allow} = \frac{12\pi^2 E}{23(KL/r)^2}, \text{ for } \left(\frac{KL}{r}\right)_c = \sqrt{\frac{2\pi^2 E}{\sigma_Y}} \leq \frac{KL}{r} \leq 200 \qquad \text{(Eq. 5.1)}$$

$$\sigma_{allow} = \frac{\left[1 - \frac{(KL/r)^2}{2(KL/r)_c^2}\right]\sigma_Y}{\frac{5}{3} + \frac{3}{8}\frac{(KL/r)}{(KL/r)_c} - \frac{(KL/r)^3}{8(KL/r)_c^3}}, \text{ for } \left(\frac{KL}{r}\right)_c \geq \frac{KL}{r} \qquad \text{(Eq. 5.2)}$$

determine the maximum end axial force of P that can be applied, for bending failure to occur about the x-x axis. **[10 marks]**

b) Ignoring the contribution of the moment, determine the maximum end axial force of P

i) for buckling failure to occur about y-y axis, using Euler's equation. **[7 marks]**

ii) for compressive failure to occur. **[3 marks]**

c) Illustrate the differences of failures in **Question 5, part a), b i),** and **b ii)** above, in terms of the magnitude of end forces leading to failure, failure modes and/or locations of failure. **[5 marks]**

End of Paper.